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THESIS

THE HISTORY AND DEVELOPMENT OF STAINLESS STEEL AND STAINLESS IRON

By

Mary Katharine Hickey
(B.B.A. Boston University 1927)

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American Stainless Steel Company
Chrysler Building Corporation
Crucible Steel Company of America
Empire State Corporation
Republic Steel Corporation

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I. INTRODUCTION

A. Statement of the Thesis Problem

It is my purpose in this thesis to discuss the history and development of the so-called "stainless" steels and "stainless" irons, and their utility in various industrial and commercial applications.

Up to the present time no material has been discovered which is absolutely stainless under any and all conditions. For this reason the objection has frequently been made that the term "stainless" does not properly designate the qualities inherent in these materials, and that "unstainable" or "corrosion resistant" would serve to describe them more accurately.(1) However, the term "stainless" has come to be used very generally throughout the steel industry in referring to this group of alloyed steels, and it will be similarly used in this discussion.

In tracing the history of these stainless materials it is important to bear in mind three distinct developments:

> 1. The experiments carried on in England by Mr. Harry Brearley, which led to his discovery in 1913 of the resistance to corrosion of steels containing a high percentage of chromium.
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> At the time of this discovery Mr. Brearley was Chief of the Research Laboratory run jointly by Messrs. John Brown & Co. Ltd. and Messrs. Thomas Firth & Sons Ltd.

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(1) Monypenny, J. H. G., Stainless Iron and Steel, Revised Edition, 1931. Preface, p. viii.

The first practical application of the material discovered by Mr. Brearley was made in 1914 when he persuaded the Cutlery Manager of Messrs. R. F. Mosley of Sheffield, England, to work some of the steel up into knives.

For reasons not entirely obvious no application for a British patent was made by Mr. Brearley, but in August, 1915, a patent was obtained in Canada (Canadian patent No. 164,622), and in September, 1916, a patent was obtained in the United States (U. S. patent No. 1,197,256). Mr. Brearley also obtained two patents in France in 1917 (French patents Nos. 483,152 and 484,693). (1)

2. In 1915, fifteen days before the application filed by Mr. Brearley, Mr. Elwood Haynes filed an application in the United States for a patent on an alloy composed of carbon and chromium. This patent was obtained by Mr. Haynes in 1919 (U. S. patent No. 1,299,404). (2)

3. From 1909 to 1912 at the Krupp Works in Germany, Drs. Strauss and Maurer of the Krupp research staff conducted a series of experiments on steels containing large amounts of chromium and nickel. These analyses are covered by German patents (Nos. 304,126 and 304,159 obtained in 1912) and by British patents (Nos. 13,414 and 13,415 obtained in 1913). (3)

From these three sources have developed the tremendous variety of stainless or rust-resisting steels being manufactured and sold today.

A large number of patents have been granted, both in the United States and abroad, covering additions to and improvements of the original patents obtained by Brearley, Haynes, and the Krupp Works. Numerous patents have also

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(1) Ibid p. 8 ff.
(2) Ibid p. 19 ff.
(3) Ibid p. 20 ff.

been obtained covering various methods and procedures to be followed in the manufacture of these alloys.

It is not the purpose of this thesis to discuss in detail the maze of patents which has developed in connection with varying analyses of stainless steels and stainless irons and their methods of manufacture. Such a discussion would be entirely beyond the scope of this thesis, and could be developed intelligently only by a person trained and experienced in the metallurgical treatment and chemical composition of the stainless alloys.

It is the purpose of this thesis to trace the history of the stainless alloys through a more detailed discussion of the original patents obtained by Brearley, Haynes, and Krupp Works, to discuss the general methods used in manufacturing the stainless alloys and the practical industrial applications that have been made, and also to present some data regarding the possible future applications of these materials for commercial and industrial purposes.

It is of particular interest to note in this connection that the development of the stainless alloys in the United States did not take place until some time after similar developments in England. In 1919, Mr. Elwood Haynes published an account of his experiments on high chromium steel.(1) Commenting on the Haynes paper in 1921, Dr. John

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(1) Proc. Eng. Soc. Western Penn., Vol. XXXV. p. 467
See footnote p. 18, Monypenny J. H. G., Stainless Iron and Steel

A. Mathews, Vice President of the Crucible Steel Company of America, stated: "We pride ourselves on being a progressive people, yet in the matter of adopting stainless steel for general use we are far behind our conservative British cousins. The use of stainless steel in Great Britain in its various applications has gone ahead very much more rapidly than it has in America."[1]

It has been possible to trace the history of these stainless alloys in England, Germany, and the United States, but the discussion of the extent of their development and their industrial uses has necessarily been confined almost entirely to the United States, due to the absence of suitable information and references regarding the industrial developments in other countries during recent years. For this reason the results shown are by no means entirely conclusive, and the extent of the future use of stainless alloys in the United States and abroad is very problematical.

It is a striking paradox that factors which, on the one hand, have greatly aided the development of the stainless alloys have, on the other hand, greatly impeded their progress. I refer to the economic conditions which have prevailed in the steel industry since 1929.

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(1) Monypenny J. H. G., Stainless Iron and Steel, p. 19 footnote

There is no doubt that many of the larger steel companies with efficient research staffs, with large experimental laboratories and equipment immediately available, and with ample time to carry on research work, have been able to expend considerable effort in developing new analyses and manufacturing processes for the stainless alloys. Had the past five years been a "boom period" in the steel industry, it is most unlikely that these same companies, in consideration of other manufacturing problems they would then have been facing, would have been able to devote the same amount of time, talent, and equipment to experimentation and research on the stainless alloys.

On the other hand, research work of this nature is extremely expensive. It must be carried on by scientifically trained and skilled metallurgical experts. Consequently, if the steel industry had been facing a more prosperous period, if the financial returns from sales of stainless materials had been larger, it is quite possible that the development of the stainless alloys would have progressed even more rapidly.

In this connection there is another important factor that must be borne in mind. That is, not only the steel industry, but practically every industrial and commercial enterprise which uses steel in its various forms, have also been in the throes of the economic depression, and for

this reason expenditures of all kinds have been kept at a minimum.

The stainless alloys, because of the nature of their composition, their method of manufacture, and the immense amount of research work required for their development and practical industrial applications, are much more expensive than ordinary carbon steels. While, in the majority of cases, the initial cost is more than offset by the length of wear, and the type of service obtained from the stainless alloys, as compared with ordinary carbon steels, the fact that stainless material is expensive has in many cases impeded or delayed its use on certain applications. It is but natural that with marketing conditions such as have prevailed since 1930 price should be the dominating factor in determining the grade or quality of material to be purchased.

In addition, it must be kept in mind that the price feature of the stainless alloys is controlled by the holders of the major patent rights. Most of the stainless materials manufactured in the United States today are manufactured under licenses granted by the American Stainless Steel Company of Pittsburgh, Pennsylvania, holders of the Brearley, Haynes, and other patents, or the Krupp Nirosta Company of Watervliet, New York, holders of the Krupp and other patents on the chrome nickel series of stainless alloys.

As previously stated, the quality of the basic material used, the care that must be exercised in the preparation of the billets and ingots, in the rolling of the steel itself, the cost of manufacture in electric furnaces, plus the money that must be spent on modern equipment, metallurgical research and experimentation, all combine to make the stainless alloys expensive to produce and consequently they must be sold at prices much higher than those obtained for the ordinary carbon steels.

As yet it has not been possible to produce the ordinary range of stainless alloys on a tonnage basis, and at extremely low prices that would compete with the prices obtained for tonnage mill rolling of carbon steels. In a few cases certain of the stainless alloys have been produced at extremely low prices, notably the so-called "rustless iron" produced by the Rustless Iron Corporation of America. This material will be discussed more in detail in a later section of this thesis. However, there has been an interesting lawsuit brought in this case, and as the original court decision is being appealed, the ultimate outcome of the case is at present very much in doubt.

It seems not unlikely that in the not too far distant future the stainless alloys will probably be produced on a more favorable commercial basis than they are being

produced at the present time. Just what the developments along this line will be is doubtful, but it is quite certain that they will be controlled in the main by general economic conditions prevailing in the steel industry and allied business enterprises, and by further metallurgical research and developments.

B. Steel as an Important Feature of our Economic and Social Structure

If the steel industry had no claim to our interest other than the fact that it numbers among its producing units the largest business aggregation in the world, the United States Steel Corporation, that fact alone would merit our attention. But the industrial development of the world, international commerce as we know it today, and the almost innumerable and ever-increasing uses of steel in our daily lives, make it essential for us to understand the economic importance of the steel industry.

The story of the steel industry is the history of the astonishing development of the United States during the last sixty years. Iron and steel a few generations ago were regarded as commercial luxuries; today they are commercial necessities. Literally thousands of articles in daily common use require steel either in their own construction, or as an agent in their manufacture.

The prime factor in the rapid growth of the use of steel was the invention, in 1854, of the Bessemer converter, which rendered it possible to make steel with great rapidity and at low cost. From the day when steel was made "by the spoonful" to the present, when the United States Steel Corporation, with several Bessemer converters and three hundred odd open hearth furnaces, is capable of producing some 65,000 tons every twenty-four hours, is a "far cry reckoned in terms of industrial development, short as the time may be in years."(1)

Another important influence in the steel industry was the development, in 1861, of the Siemens regenerative furnace, which today forms the basis of the open hearth process of manufacturing steel. Under this process a greater variety of materials may be used than can be used under the Bessemer process.

A more complete description of both of these processes is given in a later section of this thesis.

Bessemer is given the great credit for making possible the manufacture of steel in large quantities and at reasonable prices, but his process has many limitations, as will be shown later in this thesis.

Four other factors have served to greatly increase the consumption of steel in industry. They are the development of the various railroad systems throughout the

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(1) Speech delivered at the Convention of the American Society for Steel Treating, Boston, 1925. Title of address, "Fifty Years of Steel." Name of speaker not known.

United States, the development of the automotive industry, and in more recent years the development of the aircraft industry, also the development of modern architecture, notably our "skyscraper" office buildings, apartment houses, and hotels.

When the Woolworth Building in New York City, whose tower extends 792 feet above the pavements of Broadway, was completed in 1912, it was considered a marvelous engineering feat. Aside from the Eiffel Tower in Paris, the Woolworth Building at the time of its erection was the tallest building in the world. Today it is exceeded in height by five buildings in New York City. In the construction of two of these more modern buildings large quantities of stainless steel were used. The Chrysler Building at 405 Lexington Avenue rears its stainless steel clad tower 1046 feet into the air, while nearby, at 250 Fifth Avenue, on the site of the old Waldorf Astoria Hotel, the stainless steel trimmed facade of the Empire State Building extends to a height of 1248 feet above the street level.

After considering these facts, it will not be surprising to the reader to know that the greatest demand for steel consumption comes from the railroad, building, and automotive industries. And, bearing in mind the close association of these industries with our daily lives, it is easy to understand and to realize the significance of

the frequently quoted statement that "iron and steel show the real underlying trend of business."

Not only have the railroad, automotive, and building industries increased the tonnage demand for steel, but they have greatly influenced the development of many new types of steel. It is not the province of this paper to discuss the detailed metallurgical qualities desired in steels used for these varying purposes. It is sufficient to say that the steel industry has not only been able to meet, but has been able to anticipate some of the major requirements of these industries. In fact, one of the most notable developments in the steel industry within the past thirty years is the development of a wide range of alloy steels, the main purpose of which has been to comply with the varied and varying requirements of the railroad and automotive industries.

II. EFFECT OF CORROSION ON IRON AND STEEL

A. Annual Expense of Corrosion

For many years the general tendency of iron or steel to rust when exposed to the atmosphere, water, or other corroding influences was accepted as a matter of course. In fact, it was stated that "this tendency was an inherent property of the element known as iron and would in all probability never be entirely overcome."[1]

Sir Robert A. Hadfield made a survey of the losses by rusting of iron and steel all over the world and reached the conclusion that the yearly cost was over $3,500,000,000.[2] Such an estimate must necessarily be taken with considerable reservation, because of the obvious inability of anyone to correctly estimate just what amount of corrosion takes place annually, and what its probable cost would be in dollars.

B. Advantages of Overcoming Corrosion

Everyone is familiar with the general rusting of household appliances and other articles for domestic use, and, of course, realizes that this is only a very minor problem when compared with the corrosion which takes place on large engineering structures, and in various industrial applications of steel and iron.

The question of the expense is not the primary one in considering corrosion, because the tendency of iron and

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(1) Monypenny J. H. G., Stainless Iron and Steel p. 3
(2) Ibid p. 3

steel to corrode may cause very serious troubles. On machinery and in engineering structures the tendency to corrode will cause a weakening of important parts, and will result in their failure to perform their essential functions. The repair cost, loss of production, and delay caused by such corrosion are very expensive items.

In other lines of industry, and particularly in the chemical industry, corrosion not only causes the gradual deterioration of the equipment made from steel, but also causes contamination of the articles being manufactured. Hence the use of a non-corrosive or stainless metal is greatly to be desired.

For conveyor belts in factories it is desirable to have material of high tensile strength to resist wear and to carry heavy loads, also to resist the corrosive action of acids or other chemicals with which it may come in contact.

In the paper making industry it is desirable to have machinery which will be resistant to all of the various chemicals employed in the manufacture of paper. At the same time, this machinery must be of such structure and construction that it will be capable of performing the necessary cutting and beating operations required in the making of paper.

The advantages of labor saving in the use of stainless cutlery, and in the use of stainless for other household appliances are self-evident.

In fact, it might be said that in the majority of cases where ordinary steel is employed, and where corrosion is an important feature, a considerable annual saving could be effected by the use of one of the corrosion resistant or stainless materials now on the market.

III. <u>GENERAL DEVELOPMENT OF STAINLESS PATENTS</u>

The three major developments on stainless steel patents, referred to in the introduction to this thesis, will be discussed in more detail in the present section.

In any treatise on stainless steel, or stainless iron (which is simply stainless steel with a decidedly lower carbon content than was at first adopted for these alloys), it must be constantly kept in mind that up to the present time the whole field of stainless materials has been a development of the science of alloying the element carbon with the element chromium. In some cases, notably the Krupp patents, chromium has been alloyed with nickel, as well as with carbon. On many other grades of stainless various other alloys have been added to the chromium-carbon, or chromium-carbon-nickel combinations.

The reader's attention is particularly directed to the wide analysis range specified in the Brearley and Haynes patents, both of which have been successfully defended in lawsuits brought for infringement of these

patented analyses. There is little doubt that these patents permit the manufacture of a much wider range of stainless alloys than was anticipated by their original patentees. In spite of the fact that the patents cover their manufacture, there is no reason to believe that either Haynes or Brearley, at the time their first patents were obtained, had any conception of the wide variety of stainless materials, now being marketed under various trade names, that their patents would foster. This is particularly true of the low carbon stainless irons.

This fact is well brought out in the decision rendered by Judge Coleman in February, 1933, in the case brought by the American Stainless Steel Company and the Electro Metallurgical Company (subsidiary of Union Carbon and Carbide Company) against the Rustless Iron Corporation of America, in which American Stainless claimed that Rustless were violating and infringing on the Clement and Hamilton and Evans patents. This case was tried in the U. S. District Court at Baltimore.

Judge Coleman ruled that the Clement patent was invalid as the analysis manufactured thereunder was presupposed by the Haynes patent. A complete discussion of this suit is given on page 56. It is merely cited in the present instance to show that up to the present time the basic and most important patents are those obtained by Brearley, Haynes, and Krupp Works.

A. <u>The Brearley Patents</u>

The actual discovery of the resistance to corrosion of steel containing a high percentage of chromium was made by Mr. Harry Brearley in 1913. Mr. Brearley was then employed as chief of the research laboratory run jointly by Messrs. John Brown & Company, Limited, and Messrs. Thomas Firth & Sons, Limited, Sheffield, England, and was engaged in research work for the Russian government on armor piercing projectiles.[(1)]

In order to overcome erosion in rifles and guns, Brearley made in intensive study on a series of alloy steels, some containing large amounts of chromium, one of which later came to be known as "stainless steel."

During his experiments Brearley subjected numerous samples to various heat treatments and made the microscopical examinations usual in such cases. He found that many of the chromium steels were little affected by the chemical reagents generally used in preparing specimens for microscopical examination. He was impressed by these unusual characteristics and proceeded to make tests to discover the analysis range of material most resistant to ordinary corrosion, and also the type of heat treatment necessary to develop to the greatest extent this resistance to corrosion.

In 1914 Mr. Brearley persuaded Mr. E. Stuart, cutlery manager for Messrs. R. F. Mosley of Sheffield, to work

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(1) Iron Age, July 31, 1919 p. 294

some of this steel up into knives. It is stated that one of the workers in the cutlery plant at that time expressed, in language more forceful than elegant, his opinion of any person who believed it possible to make a knife that would prove resistant to staining and corrosion.

The government learned of the experiments made by Brearley, and during the World War the Minister of Munitions of Great Britain appropriated all supplies of stainless steel. They used this material chiefly for exhaust valves on aero engines, where the requirements call for a material which will be extremely strong and will resist erosion at high temperatures.(1)

Early in 1915 Mr. Brearley severed his connection with the Brown-Firth laboratories, and became Works Manager of Messrs. Brown, Bayley's Steel Works, Limited. Probably due to the pressure of his new duties, the World War, and possibly for other reasons, Brearley allowed the opportunity to obtain a British patent to pass.(2) However, a Canadian patent, No. 164,622, was obtained in 1915, and in September, 1916, Brearley obtained a United States patent, No. 1,197,256. This patent specifies the following analysis:(3)

Chrome	9 to 16%
Carbon	not over .7%

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(1) Iron Age, July 31, 1919, p. 294
(2) Monypenny, J. H. G., Stainless Iron and Steel, p. 9
(3) U. S. patent records, No. 1,197,256

In the patent Brearley specifies a typical test lot as analyzing:

Carbon	.30%
Manganese	.30%
Chrome	13.00%
Iron	86.40%

In the patent Brearley also specifies that an electric furnace should preferably be used in manufacturing the material, which he particularly recommends as being suitable for cutlery. He also states that blades made from this analysis can be hardened, tempered, and polished, under conditions similar to those used on ordinary steel, and that the blades will be unstainable.(1)

The patent also mentions that certain other elements in amounts up to 1 or 2 per cent would not affect the result obtained from the carbon-chromium combination. The elements thus specified in the patent are nickel, cobalt, copper, tungsten, molybdenum, and vanadium.(2)

Monypenny calls particular attention to the fact that at the time of the development of the Brearley patent the microstructure of high chromium steel, and the complexities of its heat treatment were not well understood. He further states, "The range of composition specified, however, does mark out wonderfully well the material useful for those technical purposes for which a steel capable of being hardened and tempered is desirable, and it is highly probable that, had the composition of stainless material

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(1) and (2) U. S. patent records No. 1,197,256

for such purposes to be fixed at the present time with the accumulated knowledge of the past few years at the disposal of the discoverer, the range chosen would not differ materially, if at all, from that laid down in 1915."[1]

U. S. patent No. 1,197,256 is now owned by the American Stainless Steel Company. The activities of this company in relation to marketing stainless steel in the United States are discussed in Section Five[2] of this thesis.

B. The Haynes Patents

As is frequently the case in scientific discovery, two investigators may be working independently at the same time, along similar lines. This was the case in stainless steel.

At the time that Brearley was working in England, Elwood Haynes was engaged in somewhat similar research in the United States, on carbon and chromium alloys.

Prior to 1912, Haynes had secured a series of U. S. patents on materials known under the trade name "Stellite." This was a series of cobalt-chromium and cobalt-chromium-tungsten alloys, which were used for making tools. This "Stellite" series proved superior in use to the best high speed steel then on the market. Some of the alloy combinations were also extremely resistant to corrosion.

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(1) Monypenny J. H. G., Stainless Iron and Steel p. 11
(2) See Section V., p. 49 ff.

Haynes published an account of his experiments in 1919.[1] From his own statement it would appear that he was chiefly interested in the use of the chromium-carbon alloy for tools, and that he had not concerned himself to any great extent with the heat treatment of the material. It is also evident that he knew little about the physical properties of the alloy he had discovered, or the possible changes that could be effected in these physical properties by suitable heat treatment. It would seem, too, that Haynes had not investigated to any extent the resistance to corrosion of varying combinations of chromium and carbon.

There is one very interesting feature to indicate that the discovery by Haynes was certainly the first of this type in the United States. In the paper referred to above, he states that after making his initial experiments, "In order to make sure that such alloys were unknown at this time, letters were written to practically all the large steel producers of the United States, asking for a non-rusting or non-tarnishing alloy, but the replies received were all of a negative character, and showed that no such alloy existed, but suggested the possible use of alloys of nickel and iron, but in no case was chrome-iron or chrome-steel even mentioned."[2]

This would indicate that to the steel makers in the United States at least, the corrosion resistant qualities

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(1) Proc. Eng. Soc. Western Penn. Vol. XXXV, p. 467
(2) Monypenny J. H. G., Stainless Iron and Steel p. 19

of steels containing a high percentage of chromium were then unknown.

Haynes' original application for a patent was rejected, but he filed a second application in 1915, actually fifteen days before Brearley filed his application in the United States. The Haynes patent was not granted until 1919, U. S. patent No. 1,299,404. This specifies a material of the following analysis:(1)

Chrome from 8 to 10% up to 50 to 60%
(Chrome 10 to 25% best)
Carbon not over 1.0%

The Haynes patent also specifies that the material should be made in an electric furnace, and that it is suitable for cutlery and edged tools, and for other purposes, such as chisels, etc.

The Haynes patent, U. S. No. 1,299,404, is also owned by the American Stainless Steel Company.

C. Analysis Range of the Brearley and Haynes Patents

As previously stated, there is a wide analysis range specified in both the Brearley and Haynes patents. The actual specimens on which Brearley and Haynes conducted their experiments were decidedly towards the lower limit of the specified range for chromium content. It is important that the reader keep this point in mind in a consideration of these patents.

It is also important to bear in mind the fact that the material on which Brearley and Haynes experimented

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(1) U. S. patent records No. 1,299,404

was not stainless until subjected to suitable heat treatment. Developments since these discoveries have proved the fact that material with a carbon content on the higher limit of the analysis range, or material with sufficient carbon to make it fall within the classification of "stainless steel," is not today stainless in the condition "as rolled" by the mill, or in the annealed condition. Stainless steel is stainless only after being subjected to suitable heat treatment to bring out its corrosion resistant qualities.

The problem of the heat treatment of stainless steel is a metallurgical one, and the heat treatment to be given to any particular type of stainless alloy depends upon the physical properties desired, as well as upon the corrosive elements or action that the material will be expected to resist.

Nor is the lower carbon "stainless iron" resistant to corrosion in its natural state, simply by the combination of certain definite percentages of chromium and carbon. Stainless iron must be subjected to some form of heat treatment, either during the rolling process, or after rolling, in order to bring out its stainless qualities.

These points are brought out now so that the reader may understand that it is not simply the combination of the elements chromium and carbon which renders the material

corrosion resistant. It is the combination of these elements, plus suitable heat treatment, which provides the necessary qualities of corrosion resistance. In other words, the corrosion resistant properties of the materials patented by Brearley and Haynes can be materially affected by heat treatment, and it is only by proper heat treatment of these alloys that suitable corrosion resistant properties are obtained.

D. The Krupp Patents

At the time Brearley and Haynes were making their experiments in England and the United States, Drs. Maurer and Strauss of the Krupp Works, Essen, Germany, were also experimenting with corrosion resistant alloys. These experiments were conducted on materials bearing relatively high percentages of chromium and nickel. In 1912 two series of patents were obtained in Germany.

In the first series, for resistance to general corrosion (not acids), the following analysis was specified:

.5	to	20.0%	Nickel
7.0	to	25.0%	Chromium

In the second series, for which resistance to acids, particularly nitric acid, was claimed, the specified analysis was:

4.0	to	20.0%	Nickel
15.0	to	40.0%	Chromium

In both series the carbon content was limited to 1.0% or less.

It would seem from these patents that at this time no discovery had been made in Germany as to the high resistance to corrosion of steels containing a relatively high percentage of chromium in combination with carbon.

English patents, Nos. 13,414 and 13,415, were obtained on these analyses in 1913, and patents were later obtained in the United States, and assigned to the Chemical Foundation, Incorporated.

Material manufactured under the Krupp patents is now manufactured in the United States under licenses issued by the Krupp Nirosta Company of Watervliet, New York, whose activities in the United States market are discussed in Section Five.(1)

The chromium-nickel corrosion resistant alloys are austenitic in character, that is, the carbon in these steels is all in solution, as contrasted with the martensitic or hardenable types manufactured under the Brearley and Haynes patents.

In this connection it must be borne very definitely in mind by the reader that the physical properties of steels of the austenitic type depend on their composition and the mechanical and thermal treatment they have received in the process of manufacture. The method of heat

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(1) Section V, p. 52 ff.

treatment on the austenitic steels is widely different from the heat treatment of the martensitic steels. The possibility of modifying the physical properties by heat treatment is much less on the Krupp austenitic steels than on the Brearley and Haynes martensitic types. (1)

E. Outgrowths of the Brearley, Haynes and Krupp Patents

From the foregoing it may be seen that the development of the wide range of stainless steels and stainless irons now being marketed in the United States and abroad originated in three distinct and separate investigations, carried on during the same period, but entirely independent of each other.

From these three sources has developed a maze of supplementary and auxiliary patents, which may be classified as developing along the following rather well-defined lines:

1. The use of high chromium contents, 25 per cent or more, with or without sufficient nickel to make them austenitic.

2. The use of higher percentages of nickel than are found in the austenitic steels of the Krupp type.

3. The addition of other metals, cobalt, copper, molybdenum, silicon, tungsten, etc., either to the plain chromium steels or to one of the other austenitic alloys. (2)

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 26
(2) Ibid, p. 27

The high chromium contents referred to in the first group were visualized under the Brearley and Haynes patents, but little practical application was made of them until recent years, when they have been adopted in many cases to withstand very high temperatures, accompanied by corrosive action.

C. M. Johnson obtained three United States patents on material referred to in group two above, i.e. material containing a somewhat higher percentage of nickel than was included in the Krupp patents. A range of about 20 to 40 per cent was specified in the Johnson patents. Johnson assigned these patents to the Crucible Steel Company of America, who manufactured under them a series of steels under the trade name, "Rezistal."

In March 1929, Crucible sold these Johnson patents to the Krupp Nirosta Company, and in exchange acquired an interest in the latter company. Crucible was then licensed to manufacture under all the patents held by the Krupp Nirosta Company.(1)

The elements mentioned in group three are added to the stainless materials for various purposes, which may be summarized briefly as follows:(2)

> Molybdenum improves resistance to acid.
>
> Copper also improves resistance to acid.

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(1) Wall St. Journal, March 20, 1929
(2) Bowman, M. A., Performance of Stainless Steels, Iron Age, July 20, 1933, p.58

Tungsten gives increased strength at elevated temperatures.

Manganese improves the ductility of the steel.

Titanium prevents intergranular corrosion. (1)

Cobalt has somewhat the same effect as nickel. Cobalt, however, has been used for only one purpose, in valves for internal combustion engines. In this case the addition of cobalt seems to give better results than can be obtained from straight chrome material. (2)

F. Development of Stainless Iron

The original application of stainless steel was for cutlery. During the World War the British government controlled the entire output of stainless steel and used this material for aero valves. In both of these cases a hardenable alloy of fairly high carbon content was necessary.

Shortly after the World War, experiments were conducted at the Brown, Bayley Steel Works in England on material containing .07 per cent carbon and 11.7 per cent chromium. The physical and mechanical properties of material thus produced were found to be ideal for several purposes. It was possible to hot work this material more easily than the higher carbon stainless steel, and the material was found to be suitable for several applications where the higher carbon steel had not proved adaptable.

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(1) Bowman, M. A., Performance of Stainless Steels, Iron Age, July 20, 1933, p. 58
(2) Monypenny, J. H. G., Stainless Iron and Steel, p. 247

Since that time a large variety of so-called "stainless irons" has been put on the market. The name "stainless iron" is perhaps erroneously used for these materials, as they are really low carbon stainless steels, the lowest of a series of varying carbon contents which may be compared to a series of ordinary carbon steels, ranging from "dead soft" to tool steels.[1]

It must be kept in mind that the analyses of these lower carbon grades are included in both the Brearley and Haynes patents.

One of the most important features of the lower carbon materials is that they form more easily than the higher carbon types. Where ease in mechanical operation is required, and where the lower carbon types will offer suitable corrosion resistance, they will be likely to be adopted, because of the fact that they are lower in price than the higher carbon types.

So far no real standardization on stainless materials has been possible. There is no type of stainless yet developed which will prove to be stainless under any and all circumstances. The requirements of each particular installation differ, and the type of material adopted will depend upon the circumstances surrounding the installation as well as upon the relative importance of the individual characteristics desired in the material.

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 24

This whole problem is a metallurgical one. The field of stainless metals is quite new, their possibilities and utilities have not begun to be realized. Economic conditions and future developments in metallurgical knowledge will determine the extent to which standardization can be applied to the immense variety of stainless steels and stainless irons now on the market.

III. GENERAL PROCESSES USED IN MANUFACTURING STEEL

Before proceeding to discuss in detail some of the specific manufacturing procedures that are followed in the manufacture of the stainless steels and stainless irons, it might be well to review briefly the four general processes used in the manufacture of straight carbon and alloy steels.

In general, pig iron and iron and steel scrap form the base of steel. The various processes of manufacturing consist in the main part of removing the impurities collected in the operation of melting the pig iron or scrap, and the addition of whatever other elements or alloying elements that are required to impart the desired characteristics to the metal.

In the process of manufacturing steel four general methods are in use:

1. Bessemer
2. Open Hearth
3. Crucible
4. Electric

A. The Bessemer Process

The Bessemer process was invented by Sir Henry Bessemer in 1854. Because of its revolutionary effect on modern industry, it is regarded by some as the greatest of all inventions, for without it the production of cheap steel in unlimited quantities would have been impossible.(1)

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(1) Walker, J. B., The Story of Steel, p. 44

The Bessemer converter is a pear-shaped vessel, varying usually from 10 to 16 feet in interior diameter, and from 12 to 20 feet in height. It is supported midway from top to bottom on trunnions, so that it may be tipped. The converter is closed at the bottom and drawn in at the top.(1)

The average Bessemer converter holds a charge of from 10 to 25 tons of molten metal.

The general procedure in the Bessemer process is to place the converter in a horizontal position and pour a charge of from 10 to 25 tons into it from the ladle. The converter is then swung back into an upright position and a charge of air is shot up through the molten pig iron. The air is blown from the air chamber at the bottom of the converter through a series of holes in the bottom grate, under a heavy pressure, which forces the cold air up through the molten metal.

The oxygen of the air combines with the carbon, silicon, and manganese in the iron, and increases the temperature of the molten mass, until all the combustible elements are burned out. Silicon and manganese burn first and then the carbon. This process continues for from 10 to 15 minutes. At the end of this time practically all of the impurities are burned out, and only the pure pig iron remains.(2)

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(1) Ibid p. 54
(2) Ibid p. 46 ff.

The Bessemer converter requires a skilled operator to handle the process correctly. The only test method used in deciding when to remove the air blast is the human eye. Various attempts have been made to apply the spectroscope to this process, but without success.

As the silicon begins to burn a reddish-yellow flame appears in the converter. Soon this flame acquires a greenish tinge on the edge, indicating that the manganese is beginning to oxidize. As the carbon begins to burn the flame becomes very bright, almost white, and flickering. This continues for a few minutes, and then begins to die out. As the flame diminishes, it indicates to the operator that the carbon is practically all burned out.[1]

The material then remaining in the converter is practically pure pig iron. To make this into steel requires the addition of varying quantities of carbon, manganese, silicon, or whatever elements are required to produce the quality of steel desired. In order to add these elements, the molten pig iron usually passes from the converter into a receiving ladle. The required elements, in exact proportions, are then added to the molten mass and the steel may then be run into ingot molds for commercial use, or, if further purification is required, this molten metal from the Bessemer converter may be

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(1) Keller, J. F., Lectures on Steel and Its Treatment p. 19 ff.

transferred into an open hearth furnace for manufacture into higher grade steel.[1]

The Bessemer process is the quickest known method for refining pig iron. From 15 to 20 minutes is required to refine approximately 15 tons.

However, it should be borne in mind that the Bessemer converter requires a charge of molten iron, and will produce from a charge of the same amount a smaller tonnage of material than can be obtained by the open hearth process, in which the charge may consist of a certain percentage of molten iron, and a definite percentage of scrap iron.

Also, the only method of control for the Bessemer converter is the human eye. The operator of the converter must watch the "boiling" operation constantly, must be able to immediately detect color changes in the flame as the elements burn off, and the possibility of human error in this process is quite great.

B. The Open Hearth Process

The open hearth process of making steel utilizes the open hearth type of regenerative furnace invented by Siemens.

There are two distinct types of open hearth furnaces, the basic open hearth, and the acid open hearth. The operation of the two furnaces is similar. Their difference is in the construction of the furnace bottom. In the

(1) Keller, J. F., Lectures on Steel and Its Treatment p. 19 ff.

basic furnace the bottom is made up of several layers of clay brick, upon which a deep lining of magnesium is placed. In the acid furnace the bottom is constructed of silica sand.

The difference in the construction of the furnace bottoms causes a different type of reaction to take place in the molten metal as it is heated.

At the present time practically all of the open hearth furnaces in use in the United States are of the basic type.

The open hearth furnaces range in capacity from 5 to 15 tons for special steels to furnaces as large as 125 tons. The average capacity is from 60 to 75 tons per heat.

The open hearth process varies in different districts, depending on the amount of available pig iron and the scrap condition prevailing in the particular mill or locality.

The general process is to use a charge of molten or cold pig iron, cold scrap iron and steel. In some cases, chiefly in the Pittsburgh district, limestone is added to the original charge of metal.

Heat is applied to the charge of metal, and when the entire mass is in a molten state, a definite amount of iron ore, iron scale, or some other oxidizing material, is put into the melt. The chemical reaction causes the entire mass to oxidize and the excess carbon and phosphorus are allowed to burn off until only the desired percentage of these elements remains.

The melter determines this point in the following manner: He watches the condition of the molten material and at intervals takes out a spoonful of the metal and places it in a test mold. When the material solidifies, it is cooled in water, broken, and the fracture tested. By a visual observation test of the fracture, a skilled tester can tell the percentage of carbon in the steel within very accurate limits. The operator must be skilled in his ability to form judgments as the quality of some 60 to 75 tons of steel depends on his judgment as to the time at which the furnace should be tapped.

In some of the larger production controlled mills a hasty laboratory analysis, taking from 20 to 25 minutes, is made. This serves as a check on the melter's observation.

Before the heat is tapped, the amount of manganese necessary for the quality of steel desired is placed in the ladle. The molten metal is then poured from the furnace into the ladle and then into ingot molds. The ingots are placed in a soaking pit, check analyses are taken for final laboratory determinations, and the particular heat is numbered. The ingots may then be reheated and rolled or hammered into whatever shape or form is desired for commercial use.

Approximately 80 per cent of the carbon and alloy

steels now manufactured in this country are made by this open hearth process, which is efficiently metallurgically controlled throughout.[1]

The open hearth process of refining metal takes from 8 to 12 hours, depending upon the quantity involved, as contrasted with the 10 to 15 minutes required for the Bessemer process. However, by using the open hearth process it is possible to exercise very close control over the melt, and to secure steel of the exact composition desired.

Mr. J. B. Walker, in "The Story of Steel," has summarized the advantages of the open hearth process as follows:

> "1. By the use of ore as an oxidizing agent and by the external application of heat, the temperature of the bath, that is, the materials in the furnace, is made independent of the purifying reactions, and the elimination of the impurities (carbon, silicon, manganese, etc.) can be made to take place gradually; the temperature and composition of the bath being under much better control than in the Bessemer process.
>
> "2. For the same reason a greater variety of raw materials can be used and a greater range of products made.
>
> "3. A very important advantage is the increased output of finished steel which can be secured from a given amount of pig iron; hence, fewer blast furnaces are required to produce the same tonnage of steel. This is explained by the fact that the Bessemer process uses all iron in molten form, whereas the open hearth process can use molten iron in smaller proportion of the total charge, together with scrap.

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(1) Keller, J. F. Lectures on Steel and Its Treatment p. 22 ff.

> "4. With the development of the basic process, it was found that the greatest advantage of the Siemens-Martin over the Bessemer was the elimination of phosphorus. While the basic Bessemer process requires pig iron with a phosphorus content of 2 per cent or more in order to maintain the temperature necessary for the reactions, the basic open hearth process permits the use of iron of less limited phosphorus content." (1)

C. The Crucible Process

The crucible process was one of the first methods used to produce high grade steels, and even today it is used to a wide extent where only small quantities of metal are to be manufactured. It has been particularly widely used since the economic depression, as it is now the custom of users of steel to order in much smaller quantities than they customarily would have ordered in the past.

The crucible process is almost entirely a melting process. The base used is small pieces of muck bar, Swedish iron, or scrap steel, and such ferro alloys as are desired in the finished steel. The material of the desired analysis is sheared into small pieces and put in the crucible, which holds from 90 to 100 pounds. The crucible is then covered, to prevent the metal from becoming contaminated by the products of combustion. The crucibles are then placed in the furnace, some of which will hold as many as 36 crucibles at a time. The process

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(1) Walker, J. B., The Story of Steel, p. 54-55

of melting takes from 3 to 4 hours, on an average. After the melting is completed, the crucibles are allowed to rest in the furnace for a short length of time, to deoxidize the metal, and then it is poured into the molds.(1)

D. The Electric Process

The electric furnace process is a decidedly new development in the steel industry. It is particularly well adapted for making high grade steels, in which it is essential that the impurities (phosphorus and sulphur) be kept at the minimum point. The more common electric furnaces are those of the Heroult type.

Practically all of the stainless steels and stainless irons manufactured in the United States today are made in Heroult furnaces. A detailed description of the manufacture of stainless materials by this method will appear in a later section of this thesis.

The heat in an electric furnace is supplied through a series of three adjustable electrodes, spaced equally apart, and inserted in the roof of the furnace. When the heating process is being carried on the electrodes are lowered from the roof of the furnace so that there is a space of about three-quarters of an inch between the bottom of the electrodes and the surface of the slag.

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(1) Keller, J. F., Lectures on Steel and Its Treatment p. 31, ff.

The electric furnace may be used to refine hot metal from a Bessemer or open hearth furnace, or it may be used both to melt and refine cold metal. In either case the slag used may be basic or acid, as desired.

The general sequence of operations in refining a charge of metal are described by Walker as follows:

> "<u>First</u>: Twenty-five tons of blown molten Bessemer metal or open hearth metal is poured in.
>
> "<u>Second</u>: The electric current is turned on.
>
> "<u>Third</u>: 1,400 pounds of lime, and if Bessemer metal is used, 900 pounds of iron oxide are added. This forms a slag for the removal of phosphorus.
>
> "<u>Fourth</u>: After the phosphorus has been reduced from .09 to .008 of 1 per cent, the preliminary or oxidizing slag is removed from the furnace and a new (reducing) slag is made by shoveling in 1,100 pounds of burnt lime, 200 pounds of sand, 200 pounds of fluorspar, and 200 pounds of coke dust --all for the purpose of deoxidizing the metal and eliminating sulphur.
>
> "<u>Finally</u>, when the metal in the charge has been thoroughly refined, the proper amount of manganese, nickel, vanadium, chromium, or other alloy is added to produce the alloy steel desired." (1)

The capacities of the electric furnaces vary, but 40 tons is an average size.

The time required to give the material the treatment which Walker describes takes from four to four and one-half hours.

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(1) Walker, J. B., The Story of Steel, p. 51-52

The electric process is of great benefit in manufacturing high grade steels. It is possible to control the temperature very accurately, and the material may be tested frequently. The entire treatment may be accomplished in the furnace, rather than in the ladle. Hence, the resulting product can be made very free from mechanical defects. The electric furnace has another advantage in that it will make steel of just as high quality as the crucible process and in much larger quantities, 10 to 50 tons by the electric process, as compared to 100 to 150 pounds that can be produced under the crucible process.

IV. THE MANUFACTURE OF STAINLESS STEEL AND STAINLESS IRON

In the United States at the present time practically all of the stainless alloys are made in electric furnaces, chiefly in those of the Heroult type. The only exception is some slight amount of stainless iron, which is made from reclaimed stainless scrap, melted in electric induction furnaces.(1)

Several procedures can be followed in the processing and manufacture of the stainless alloys, and, in addition to patents on analyses, several patents have been obtained on processes of manufacture. However, many of the methods patented are quite similar in procedure, and with the possible exception of the Wild process, used by the Rustless Iron Corporation of America in manufacturing some low carbon stainless irons, they seem to be about equal in expense. The validity of the Wild patents, under which Rustless are manufacturing, is at the present time the subject of court action. This phase of the stainless iron situation is discussed quite fully in a later section of this thesis.(2)

It is not intended to describe here in detail the actual manufacture of the stainless alloys, but simply to mention in passing some of the important details in connection with these materials.

The high cost of all types of the stainless alloys,

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(1) Field, A. L., Manufacture of Stainless Iron, Metal Progress, February, 1933, p. 13
(2) See Section VI, p. 56 ff.

as contrasted with ordinary carbon steels, is due very largely to the expense of producing suitable kinds of ferrochromium to be used in their manufacture. Chromium is the chief element used to give these alloys their corrosion resistant qualities, and in the types now used commercially the necessary properties are obtained either from high percentages of chromium, or from definite percentages of chromium in combination with the element nickel.

Although chromium is a very important element in the stainless alloys, carbon is also an essential constituent of these metals.

Ferrochrome alloys may be produced cheaply from the mineral chromite ores which occur abundantly and are not very expensive. The objection here is that this ferrochrome contains carbon in higher percentages than can be used in manufacturing the stainless alloys, although this ore is very useful for making many types of alloy steels containing only small percentages of chromium and relatively large percentages of carbon.

To produce the low carbon ferrochrome needed for manufacturing the stainless alloys, two methods are possible:

> 1. Eliminating the carbon from the high carbon alloys already available; or
>
> 2. Producing carbonless alloy at the outset by using some other reducing agent than carbon. (1)

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 462

Both of these processes are expensive and increase the cost of the stainless alloy. However, up to the present time, aside from the Wild process previously referred to, no vastly cheaper method of procedure has been very extensively adopted, although several processes have been patented.

The procedure to be followed in making stainless steel in an electric furnace depends on the charge to be used. If the necessary chromium is to be obtained entirely by the addition of suitable ferrochrome, ordinary steel scrap is first melted in the furnace, and, if necessary, the carbon content is reduced to a lower figure by the use of an oxidizing slag. This oxidizing slag is then replaced by a non-oxidizing slag, and the ferrochrome and any other essential alloys are added. After the addition of the ferrochrome great care must be taken to avoid contamination of the bath by any matter containing carbon, as the element carbon is easily and greedily absorbed by the molten metal, and particularly so after the ferrochrome has been added.

In cases where stainless steel scrap forms a part of the charge, the procedure is slightly different from that followed in the above case. There is usually no attempt made to reduce the carbon content of the scrap by an oxidizing slag. For this reason it is obvious that the stainless scrap to be used must be carefully graded as to carbon

content.

The type of ferrochrome to be added to this charge will depend both upon the carbon and chromium contents of the stainless scrap being used in the charge, and upon the amount of these elements desired in the finished product. For the very low carbon stainless iron only the practically carbon free ferrochrome can be used, but the lower priced grades of ferrochrome, in which the carbon content runs from .5 to 1.0 per cent may be used for the cutlery types of stainless steel in which there is a carbon content of about .3 per cent in the finished steel.(1)

Because of the very high cost of the low carbon ferrochrome, and the fact that this grade is absolutely essential for the low carbon stainless irons and stainless steels, which in most cases sell at lower prices than the grades higher in carbon content, several attempts have been made to introduce chromium into the charge direct, without first having to manufacture the expensive ferrochromes. An interesting array of patents has been obtained, the most successful of which is the Hamilton and Evans process, rights to which are now owned in the United States by the American Stainless Steel Company, which patent they claimed was violated by the Rustless Iron Corporation. This claim formed the basis of the suit now

(1) Monypenny, J. H. F., Stainless Iron and Steel, p. 462 ff. (contains complete description of melting procedure, etc.)

pending against the Rustless Iron Corporation, who use the Wild process patents in their method of manufacture. A discussion of both the Hamilton and Evans and Wild patents appears in a later section of this thesis, and it does not seem necessary to repeat the discussion here.

Whatever process is followed in the manufacture of the stainless steels, and irrespective of the type of material being manufactured, it is necessary to exert far greater care than is required on straight carbon or the more usual types of alloy steels.

It is absolutely necessary that the molten bath and the slag be in good condition before the metal is tapped from the furnace. Where the steel has not been "killed" perfectly, the ingots will contain blowholes, accompanied by segregations in spots. This feature is particularly undesirable in any grade of steel, but especially so in the corrosion resistant types, because these segregations lessen corrosion resistance at these points.

The methods used in tapping stainless steel from the furnace into the ladle, and the pouring into the ingot molds, do not differ materially from the methods used on carbon steels. However, because of the greater cost of stainless material, and the difficulties that may be encountered in later operations in manufacture, and also after the steel is put into service, due to surface defects

or internal structural unsoundness, it is particularly important that every care be taken to insure the ingots being as metallurgically sound as possible, and free from any avoidable defects. For this reason the stainless steel ingots are examined most carefully for surface defects, and if any defects are found, they are removed by machining.

Steels which are supplied to the manufacturer in the heat treated condition are usually given a pickling operation, after the heat treatment has been accomplished. This pickling serves to remove any surface defects which may have been present after the heat treating.

Some of the austenitic steels, particularly those of the 18-8 type, and also some of the stainless irons which are used for stampings, etc., are supplied by the manufacturer with a very bright polished surface.

Whatever the type of stainless that is furnished, if it is not to be machined or heat treated by the consumer, great care must be taken to see that the surface is free from all inclusions, and that the steel contains no noticeable structural defects.

No steel mill can guarantee stainless material to withstand any and all corrosive actions, but they do guarantee that the material will be of sound structure and they will agree to replace any material which proves defective when properly worked and treated, and when used

for the purpose specified by the consumer at the time he placed his order with the steel mill. This proviso is necessary in the guarantee because the physical properties of the stainless metals are very variable, and the best results can be obtained only by strict adherence to methods of working and heat treatment prescribed by the manufacturer of the steel.

The whole field of stainless metals has opened up a great opportunity for metallurgical research. There seems to be as great a variety of stainless metals as there are possible combinations of chromium, carbon, and other alloys.

The type of stainless material to be used will in every case depend on the purpose to which it is to be adapted. In some applications certain physical characteristics are most to be desired, and in other cases different characteristics must be dominant.

For this reason, although up to the present time there has been a considerable amount of standardization on general processes to be used in manufacturing the stainless alloys, there has been no standardization possible on grades of stainless to be supplied. Each stainless application is treated as an individual problem, and practically every order must be "tailor-made" to suit the consumer's needs.

V. MARKETING THE STAINLESS ALLOYS IN THE UNITED STATES

A. The Dominant Organizations Holding Patents

The marketing situation on the stainless alloys in the United States is quite interesting, as all rights to the major patents are owned by two holding companies who do not themselves engage in the manufacture of steel, but who issue licenses to independent steel companies who manufacture under their patents. In both cases the licensees pay a per pound royalty on all of the tonnage manufactured under the patent rights.

Another interesting feature is that patents owned by one of the holding companies do not in any way conflict with patents owned by the other company, and it is, therefore possible for the independent steel producer to obtain licenses from both of the holding companies, and manufacture a wide variety of stainless alloys.

The American Stainless Steel Company of Pittsburgh, Pennsylvania, owns all United States rights to the Brearley and Haynes patents. Rights to the Krupp patents in the United States are owned by the Krupp Nirosta Company of Watervliet, New York.

The Rustless Iron and Steel Corporation is a holding company owning practically all of the stock in the Rustless Iron Corporation of America, which corporation owns several United States patents for the manufacture of low carbon stainless iron.

The position of these three companies will be discussed in detail.

There are a few smaller companies, holding lesser patent rights, but the majority of the stainless material manufactured and sold in the United States today is manufactured under patents held by the American Stainless Steel Company, Krupp Nirosta Company, or Rustless Iron Corporation.

1. American Stainless Steel Company (1)

The American Stainless Steel Company was incorporated in 1917. At that time the only patent owned by the company was Brearley patent No. 1,197,256. The company also owned the Haynes application, which later resulted in U. S. patent No. 1,299,404. In 1919 the company acquired Cox patent No. 1,333,654 and Patch and Furness patent No. 1,206,902. In 1929 the company acquired Clement patent No. 1,365,091 and a process patent issued to Hamilton & Evans, No. 1,432,289.

The production of the company reached 500,000 lbs. for the year 1918. The company reports rather indifferent progress for the next three years but beginning with 1922 its annual tonnage began to increase steadily and rapidly until it reached 22,000,000 lbs. for the year 1929. The years of the depression decreased this figure, and the tonnage in 1932 amounted to but 7,200,000 lbs. Conditions showed an improvement in 1933 when 10,900,000

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(1) All data furnished by the American Stainless Steel Co.

lbs. of stainless were manufactured under licenses issued by this company.

A complete list of the companies licensed to manufacture under licenses issued by the American Stainless Steel Company follows:

Allegeheny Steel Company
Bethlehem Steel Company
Carpenter Steel Company
Colonial Steel Company
Columbia Tool Steel Company
Crucible Steel Company of America
Henry Disston & Sons
The Duraloy Company
Firth Sterling Steel Company
Halcomb Steel Company
Heppenstall Company
Jessop Steel Company
Latrobe Electric Steel Company
Ludlum Steel Company
Midvale Company
National Forge and Ordnance Company
Republic Steel Corporation
Simonds Saw & Steel Company
Union Electric Steel Company
Universal Steel Company
Vanadium Alloys Steel Company
Vulcan Crucible Steel Company

<u>MANUFACTURERS OF CASTINGS:</u>

Brighton Electric Steel Casting Company
Chapman Valve Manufacturing Company
Chrome Alloy Products Incorporated
Cooper Alloy Foundry Company
Empire Steel Casting Company
Hartford Electric Steel Corporation
Hobart Manufacturing Company
Lebanon Steel Foundry
Michiana Products Corporation
Sivyer Steel Casting Company
Union Spring and Manufacturing Company
Wehr Steel Company

LICENSED IMPORTERS:

Thomas Firth & John Brown Ltd. Montreal, Canada,
(representing Thomas Firth & John Brown Ltd.
Sheffield, England)
A. Johnson & Co. Inc. New York City,
(representing Avesta Iron & Steel Works,
Avesta, Sweden)
Poldi Steel Corporation of America, New York City,
(representing the Poldi Steel Works,
Prague, Czecho Slovakia)

In addition to the above lists, there are several finished product manufacturers in Europe who are licensed to ship their stainless steel goods into the United States, under licenses issued to them by the American Stainless Steel Company.

The products of the above companies are sold throughout the United States under various trade names, but the analyses fall within the limits imposed by patents owned by the American Stainless Steel Company.

All of the patents held by the American Stainless Steel Company cover steels of the chromium carbon types. The company does not own any patents at all on the chromium nickel grades.

In 1923, a decision favorable to the American Stainless Steel Company was rendered in a suit brought by the company against the Ludlum Steel Company, claiming infringement of the Haynes and Brearley patents. Since that time the Ludlum Steel Company has obtained a license to manufacture under patents held by the American Stainless Steel Company.

2. The Krupp Nirosta Company

The information available concerning the activities of this company is somewhat fragmentary, as it has never been willing to supply data through the recognized commercial rating companies, although reports of its activities have appeared from time to time in the Wall St. Journal, and other trade publications.

No complete list of the patents held by this company is available, but they all cover steels of the chrome nickel variety. This group of steels first attained popularity in the United States in 1928, although they had been used on the continent some time previously, and scattered applications had been made in the United States.

The Krupp Nirosta Company is a holding company established at Watervliet, New York, by the Krupp Works of Essen, Germany, and the Ludlum Steel Company, of Watervliet, New York.(1) The primary patents obtained by the company were those referred to on pages 23 and 24 of this thesis, the discoveries patented by Drs. Strauss and Maurer. Dr. Strauss later obtained U. S. patent No. 1,339,378 covering the higher chromium type, and later assigned this patent to the Chemical Foundation Incorporated.

Materials manufactured under the several Krupp patents are sold at the present time throughout the United States under various trade names, the best known brands being

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(1) Wall St. Journal, March 7, 1929

Allegheny Steel Company's "Allegheny Metal," Crucible Steel Company's "Rezistal," and Republic Steel Corporation's "Enduro." These are all variations of what is commonly known as the "18 and 8" type, analyzing approximately 18.0 per cent chromium and 8.0 per cent nickel.

Some of the companies licensed to manufacture under the Krupp patents are:

Allegheny Steel Company
Babcock & Wilcox Tube Company
Central Alloy Steel Co. (subsidiary of Republic Steel Corporation)
Crucible Steel Company of America
Henry Disston & Sons
Driver Harris Company
Firth Sterling Steel Company
Ludlum Steel Company
Lukens Steel Company
Newton Steel Company
Sharon Steel Hoop Company
Spand, Chalfant & Company
United States Steel Corporation
Wallingford Steel Company

A feature of the Krupp licensing arrangements is the agreement of the holding company to supply technical aid to the licensees.[1]

(1) Journal of Commerce, April 23, 1931

3. <u>The Rustless Iron Corporation</u>

The Rustless Iron Corporation of America occupies an unique position in the stainless industry in the United States. This is the only large company whose entire output is limited to the lower carbon stainless alloys, familiarly known as "stainless irons."

The company markets several grades of these materials under the brand names of "Defirust," "Special Defirust," "Defistain," and "Defiheat."

The International Rustless Iron Corporation was reorganized in August 1933, and its name changed to the Rustless Iron & Steel Corporation. This company acts as a holding and licensing company, and at one time it owned 72 basic process patents in 32 different countries.(1) In September, 1931, the corporation sold its foreign patents exclusive of those in Canada and Mexico, to a European group in exchange for 1,000,000 shares of the corporation's common stock.(2)

The Rustless Iron Corporation is a subsidiary of the Rustless Iron & Steel Corporation. The latter company came into considerable prominence in December, 1930, when the Ford Motor Company announced the use of the company's product on its newest automobiles.

The Rustless Iron Corporation of America occupies the old Hess Steel Company plant at Baltimore, Maryland. It

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(1) and (2) Poor's 1931 Manual and cumulatives

manufactures the chrome alloys into semi-finished form suitable for conversion into finished products.

At one time the company had arrangements to have this semi-finished material converted into cold rolled stainless strip, in which form it was marketed to various manufacturers. One of its conversion agents was the Superior Steel Corporation.

Rustless owns several United States patents, among them Wild patents No. 1,586,590, No. 1,586,591, and No. 1,586,592. U. S. patent No. 1,586,591 was the basis of the suit brought against Rustless by the American Stainless Steel Company, who claimed that this Wild process patent is a violation of their Hamilton and Evans process patent, No. 1,432,289. The court decision in this case, which is discussed in the next section of this thesis, is particularly interesting, and leaves the future of the Rustless Iron Corporation somewhat in doubt.

No data is available as to the exact patent rights held by the Rustless Iron Corporation, nor as to the licenses granted by it to other manufacturers. The corporation refused to respond to the writer's request for information regarding patents, possibly due to pending court action.

VI. AMERICAN STAINLESS SUIT AGAINST RUSTLESS IRON FOR PATENT INFRINGEMENT

A. Basis of Suit

In 1929 the American Stainless Steel Company et al brought suit against the Rustless Iron Corporation of America, claiming that the corporation's Wild patent, No. 1,586,591, violated the Hamilton and Evans process patent, No. 1,432,289, and also that the analysis manufactured by Rustless Iron infringed on Clement product patent, U. S. No. 1,365,091, owned by the American Stainless Steel Company.(1)

On February 28, 1933, Judge Coleman rendered a decision in the U. S. District Court at Baltimore, in which he stated that the Clement patent had been anticipated by Haynes patent, U. S. 1,299,404, and was, therefore invalid. Inasmuch as the Clement patent was declared to be invalid, there was no necessity of discussing infringement on that basis.

Judge Coleman also ruled that the Hamilton and Evans patent was invalid because its essential features were the same as those of an earlier patented process for producing ferrochromium (Price U. S. patent No. 865,609), although he did state that the plaintiffs (American Stainless Steel Company) had sustained the burden of proving that the process of manufacture followed by the defendant (Rustless Iron

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(1) Baltimore Post Gazette, April 29, 1933.

Corporation of America) under the Wild patent No. 1,586,-591 was in all respects a duplication of the Hamilton and Evans process.

The decision by Judge Coleman is particularly interesting as the Haynes patent, which he declared anticipated the Clement, is also owned by the American Stainless Steel Company.

American Stainless has appealed the decision of the lower court, and it seems quite likely that the appeal will be decided in its favor, particularly in the light of the court's remarks in the original trial.

The trial was extremely interesting as metallurgical experts from both the United States and Europe testified. It is especially important to the Rustless Iron Corporation as practically all of their business is concerned with the manufacture of these low carbon stainless alloys.

In order that the reader may have a clearer understanding of the two processes, I have quoted the following excerpts from testimony introduced at the trial.

1. <u>Wild Process Patent U. S. 1,586,591</u>.

This process is claimed to be primarily a smelting operation. Any furnace may be used, provided that it is capable of maintaining complete fusion of the metals throughout the process, and of permitting the finished product to be poured or tapped into the molds.

A brief description of the process follows:

"A 500 lb. bath of ferrosilicon alloy was prepared by the addition to a bath of molten low carbon steel of a high silicon ferrosilicon (83 per cent silicon) of low carbon content in such quantity as to give a melt containing 9 per cent silicon. A portion of the charge of the slag forming reagent, mainly a mixture of lime and fluor spar was added to the bath and there was then introduced in successive charges 440 lbs. of chrome iron ore, assaying 52.8 per cent chromium sesquioxide Cr2O3, and the remainder of the charge of slag forming agent as required to make up the oxidized silicon, to increase the fluidity of the slag, and to assist in obtaining a good yield of reduced metal. Total charge of slag forming material amounted to 40 lbs. of lime and 24 lbs. fluor spar. On completion of reduction a small proportion of deoxidizer such as manganese, ferromanganese, or aluminum was added, according to known practice, to insure a sound metal capable of casting into molds of shape desired. Resulting analysis was chrome 12.95 per cent, carbon .09 per cent, silicon .36 per cent, manganese .20 per cent, sulphur .032 per cent, and phosphorus .046 per cent. Amount of stainless iron obtained was 484 lbs." (1)

2. Hamilton and Evans Patent U. S. 1,432,289

The Hamilton and Evans process, which Judge Coleman declared was substantially duplicated in the Wild process, is conducted as follows:

"The furnace may be charged with 1000 lbs. of scrap substantially carbon free and 8 per cent or 10 per cent of limestone, which is brought to a molten condition. The first slag formed thereon is allowed to eliminate impurities. Molten metal is then covered with preferably a mixture of 60 lbs. limestone, 18 lbs. fluor spar, and 12 lbs. mill scale. Heat is applied until the reception slag formed thereby is brought to a molten condition. When the slag is brought to a temperature sufficient to effect reduction, 450 lbs. of chrome ore, preferably ground and calcined, with 120 lbs. of aluminum, are gradually added to the slag. Within a few

(1) Federal Supplement Vol. 2, 1933. Pages 742-756

> minutes after this addition the reduction will be completed and reduced metals will have entered the molten mass beneath the slag. It is possible to use either the electric or open hearth furnace, but for stainless iron the use of carbon for the melting hearth should be avoided." (1)

From the foregoing data it will be seen that both the Wild and Hamilton and Evans processes are essentially smelting processes, substantially the same in performance and entirely the same in effect, that of producing low carbon stainless iron by introducing ferrochrome direct into the original charge of the furnace. This is the procedure commonly used in steel plants, the variations occurring in the manner in which the ferrochrome is introduced and in the deoxidizing procedure followed.

From the court's statements it would seem to be evident that there is infringement by the Rustless Iron Corporation on patents held by the American Stainless Steel Company, although not strictly on the basis on which the current lawsuit was brought.

The final outcome of this current lawsuit certainly will have a material bearing on the future of both of the companies involved, as well as upon the future applications of stainless iron in the United States, as up to the present time Rustless have been widely underselling the licensees of the American Stainless Steel Company.

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(1) Federal Supplement Vol. 2, 1933, Pages 742-756

VII. TONNAGE OF STAINLESS MATERIALS MANUFACTURED IN THE UNITED STATES

A. General Types

From data previously given the reader can easily understand that a great many patents for analyses and for processes have developed in connection with the various grades of stainless steels and stainless irons. In advertising data stainless is frequently referred to as "the metal of endless possibilities." It seems that this same phrase might also be used in referring to the feature of patents.

However, the reader must remember that the entire field of stainless metals is a new one, and that increased metallurgical knowledge frequently makes changes in analyses or processes desirable. The applications of stainless metals have been widely diversified and will doubtless continue to be so. Stainless metals cannot be arbitrarily substituted for the cheaper grades of steel, and their usefulness will probably be based on the existence of requirements which cannot be satisfactorily served by ordinary steels, and even then only when the advantages to be gained will justify the additional cost.

In spite of the wide diversification of applications, there may be said to have developed a half a dozen distinct types of stainless materials, whose salient features

are summarized by Monypenny as follows:[1]

"1. Stainless irons and steels containing 12 to 14 per cent chromium, a family of steels which, of all those classed under the term stainless, most readily approaches ordinary carbon steel in the extent to which mechanical properties can be influenced by heat treatment processes and by variation in carbon content. This group may be regarded as a series of high tensile steels possessing great resistance to corrosion.

"2. Stainless irons containing 16 to 20 per cent chromium. These are soft alloys which, in general, are brittle under impact and are not amenable to heat treatment operations. . .
Steels containing about 25 to 30 per cent chromium together with not more than about .5 per cent carbon may also be included in this group. These steels have mechanical properties very similar to those of the 16 to 20 per cent chromium irons except that they are somewhat harder and less ductile than the latter. They are mainly used for heat resisting purposes.

"3. Low carbon steels containing 16 to 20 per cent chromium, which possess the capacity of being hardened and tempered, due to a small content of nickel. The mechanical properties of these steels are influenced by heat treatment and by variation in carbon content in a similar manner to those of group 1, though the range of hardness values is more restricted than in the latter.

"4. Austenitic chromium-nickel steels of which the Krupp "V.2.A" is the prototype; these are the most generally used of the austenitic steels. They may only be hardened by cold work and the effectiveness of heat treatment operations is confined to the removal of cold working effects and the production of certain structural characteristics necessary from the point of view of stability against corrosive attack.

"5. Steels of group 4, whose resistance to certain severely corrosive chemicals has been increased by the addition of such metals as copper, molybdenum, silicon, tungsten.

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 518-9

> "6. Austenitic steels of high nickel content whose main features are great strength and resistance to oxidation at high temperatures, their chromium content may vary considerably, depending on the service required of them, and additions of other metals, e.g., tungsten and silicon, are occasionally made in order to further enhance their special properties." (1)

This classification serves to make the situation less complex, particularly so when it is noted that the steels referred to in groups 5 and 6 are distinctly "special purpose" steels whose application up to the present time has been somewhat limited.

The steels included in group 1 are those that most closely resemble ordinary carbon steels in their response to hardening and tempering operations. It was found in many cases that steels of this group did not possess satisfactory corrosion resistance, but efforts to improve this condition frequently led to some decrease in their response to heat treatment. Because of this fact, in selecting a steel from the above six groups, it is frequently necessary to compromise between the conflicting requirements of corrosion resistance, mechanical properties, and ease of fabrication into various forms. The steel selected will be the one best adapted to the most important of these requirements.

Not even the most enthusiastic promoters of stainless alloys claim that they are a panacea for all the evils

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 518-9

that have frequently accompanied the use of ordinary carbon steels. The steel manufacturers themselves realize better than anyone else that the stainless alloys do not in any sense approach a state of perfection. For this reason all the large manufacturers of stainless alloys maintain extensive metallurgical laboratories, and efficient technical research staffs, whose duty is to make a thorough study of each individual proposed application of stainless, and to recommend the type of material that will be best adapted to the needs of the particular installation.

B. Amount of Stainless Manufactured

A survey was made by "The Iron Age" in the early part of 1933, to determine the exact tonnage of the stainless alloys being manufactured in the United States. They solicited all the licensees of the American Stainless Steel Company and the Krupp Nirosta Company, as well as the few producers who do not operate under patents owned by these two companies. In most cases excellent cooperation was experienced, and although the statistics are not entirely complete, they serve to show the general trend of the manufacture of the stainless alloys during the years from 1929 to 1932.

In this survey it was found that the leading grade manufactured was the Krupp "V.2.A." type, an austenitic steel, called in the table "18 and 8," containing approximately 18.00 per cent chromium and 8.00 per cent nickel.

This grade has led in production in all years.

The reader's attention is particularly directed to the fact that the following tables include only the stainless or rustless steels, and do not include statistics on any of the co-called "stainless-clad" or "rustless-clad" or "Two-score stainless," all of which are simply types of stainless coatings applied to regular carbon steel.

PRODUCTION OF STAINLESS OR RUSTLESS STEEL IN THE UNITED STATES

(Gross Tons)

Ingots:	1929	1930	1931	1932 *
18 and 8	16,935	28,018	11,845	7,400
12 to 14% Chrome (approx.)	11,694	7,088	4,353	2,330
16 to 18% " "	8,138	6,425	6,013	5,425
All other (Chrome or Chrome and Nickel)	2,370	2,244	1,959	3,465
Not allocated	150	381	500	530
Total	39,287	44,156	24,670	19,150

Castings:	1929	1930	1931	1932 *
18 and 8	55	166	151	269
12 to 14% Chrome (approx.)	10	10	20	15
16 to 18% " "	25	64	129	159
All other (Chrome or Chrome and Nickel)	1,925	2,099	1,515	1,232
Not allocated	934	676	342	191
Total	2,949	3,015	2,157	1,866
Grand totals (ingots and castings)	42,236	47,171	26,827	21,016

* Estimated

C. <u>General Characteristics of the Stainless Metals</u>

As explained at the outset of this thesis the word "stainless" does not accurately describe the properties of these metals. This label was adopted in the first rush of enthusiasm that greeted the Brearley and Haynes discoveries, and has been generally used throughout the steel trade since that time.

Not only do these alloys remain unaffected by the ordinary exposures to rust, stain, tarnish, corrosion, and many of the acids that readily attack iron and carbon steel, but in addition the so-called "stainless" metals resist oxidation at temperatures up to 2000 degrees Fahrenheit. Also these alloys are ductile and can be rendered readily workable, yet they are from 50 to 400 per cent stronger than mild steel. The commercial grades of stainless offer a range in tensile strength of from 60,000 to 200,000 pounds per square inch. They have, when hardened and polished, the appearance of nickel plated wear, yet they will not tarnish.

Briefly then, "<u>STAINLESS - The Metal of Endless Possibilities</u>" has "the inherent and combined characteristics of:

1. Tremendous strength
2. Resistance to corrosion, high temperatures, erosion, and abrasion
3. Ability to take and permanently retain a highly polished surface." (1)

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(1) American Stainless Steel Company booklet, Stainless in Industry, p. 5

"Stainless materials are furnished in plates, shapes, sheets, bars, rods, flats, strips, tubing, wire, forging blanks, billets, ingots, castings, shot, etc., hot rolled, pickled and box annealed in blue, silver grey, or polished surfaces--in hard, tempered, soft, and dead soft grades.

"Stainless can be rolled, drawn, stamped, forged, pressed, machined, cast, spun, punched, brazed, soldered, welded, ground, and polished."[(1)]

From these two paragraphs one can readily picture the extensive possible uses of stainless, the endless possibilities of life extension in the substitution of stainless for those materials that crumble and disappear under the common conditions of service, and the endless savings possible in weight of material because of the enormous tensile strength of stainless, which may be made as much as 400 per cent greater than that of mild steel.

The estimate of $3,500,000,000 as the total annual loss by corrosion is a staggering figure, and "the effect on our natural resources can only be realized when we consider that seven pounds of coal are wasted every time a pound of ferrous metal is lost."[(2)]

Patented analyses and processes now make it "commercially practicable and economically possible to substitute

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(1) American Stainless Steel Company booklet, Stainless in Industry, p. 5
(2) Ibid p. 6

stainless metals which have the inherent and combined characteristics of tremendous strength, resistance to corrosion, high temperatures, and erosion and abrasion, and ability to take and permanently retain a highly polished surface, for those ferrous and non-ferrous metals and alloys which may possess one or the other of these cardinal characteristics, but not any two, or all three, in inherent combination."(1)

The following list includes several of the corrosive reagents against the action of which the stainless metals are immune, either wholly or practically so.(2)

Acetic Acid	Cotton Oil Fatty Acids
Acetone	Ethyl Alcohol
Alcohol	Foodstuffs
Alkalies	Formic Acid
Ammonia	Fruit Acids
Ammonium Carbonate	Fruits
Ammonium Nitrate	Gasoline
Ammonium Sulphate, 10%	Glue
Baking Oven Gases	Hydrocyanic Acid
Benzine	Ink
Benzol	Iodine
Blood	Lactic Acid
Boric Acid	Lemon Juice
Calcium Chloride	Lime
Carbolic Acid	Lysol
Carbon Dioxide	Magnesium Carbonate
Carbon Tetrachloride	Magnesium Sulphate
Caustic Soda	Meats
Chlorine	Mercuric Chloride, Dilute
Chlorosulphonic Acid	Mercury
Citric Acid	Milk
Copper Sulphate	Molten Lead

(1) American Stainless Steel Company booklet, Stainless in Industry, p. 20
(2) Ibid p. 19

Molten Tin
Molten Type Metal
Nitre
Nitric Acid
Novocaine
Oils
Oleic Acid
Phosphoric Acid
Potassium Chloride
Potassium Cyanide
Potassium Hydrate
Potassium Oxalate
Pyrogallic Acid
Sea Water
Silver Bromide
Soap
Sodium Acetate
Sodium Acid Carbonate
Sodium Carbonate
Sodium Hydrate
Sodium Chloride
Sodium Salicylate
Sodium Thiosulphate
Soft Soap
Sour Milk
Steam
Stearic Acid
Sugar
Sulphur Dioxide
Tannic Acid
Tannin
Tartaric Acid
Thymol
Vegetables
Vinegar
Water
Weathering
Zinc Chloride

This list is not the result of a series of special tests, but is simply a comprehensive summary of various data accumulated from time to time through laboratory study.

A practical discussion of the manner in which the stainless metals have been employed to resist these various corrosive influences is given in the following pages.

VIII. PRACTICAL INDUSTRIAL APPLICATIONS OF STAINLESS STEEL AND STAINLESS IRON

A. Cutlery

The very first application of stainless steel was for cutlery, when knives of the Brearley material were manufactured at the Mosley plant in Sheffield, England. The use of stainless for cutlery has developed rapidly and approximately 50 per cent of the cutlery knives manufactured today have stainless steel blades.

Stainless steel for the better grades of cutlery has been fairly well standardized with a chromium content of from 12.0 to 14.0 per cent, carbon approximately .3 per cent.

Special steels have also been developed to satisfy the demand for a very sharp and permanent cutting edge, such as is required on butcher knives.

When stainless was first introduced in the cutlery industry, one of the problems that confronted the manufacturers of table knives, and particularly manufacturers of knives with sterling silver handles, was the matter of finish on the blade. Much research work was done on this problem, and at the present time it is possible to obtain knives with the so-called "mirror finish" blades, which have a very bright, highly polished surface. Some manufacturers call this a "satin finish."

The Brearley type of stainless is not stainless unless heat treated. Consequently, the entire cutlery trade had to be educated in the necessary processes of heat treating these blades successfully. In many cutlery plants this meant the installation of heat treating equipment in which the temperature range could be better controlled, and kept within closer limits than were necessary with the regular carbon cutlery steels previously used. To a very appreciable extent the introduction of stainless steel has revolutionized cutlery manufacturing processes.

After the development of table cutlery, it naturally followed that stainless would be adopted for other types of knives, particularly for pocket knives, for knives to be used in other industrial applications--for cutting hides, leather, etc., as well as for scissors and for surgical instruments. In practically all of these applications stainless steel of the Brearley type is used.

For the manufacture of cheaper grades of table cutlery and kitchenware, such as spoons, forks, one-piece knives, and various kitchen utensils, the heat treating necessary on the Brearley type of stainless precluded its use. After considerable experimenting it was found that a soft stainless iron (preferably not under 14.0 per cent chromium) could be used successfully, as the cold forming

operations given these articles in the process of manufacture would provide the necessary stiffness in the finished pieces.

On such applications steel of the Krupp austenitic variety will also prove very satisfactory. However, price is the dominating factor on these cheaper lines of merchandise and the stainless iron type has been widely adopted for such applications.

In several recent government bids for cutlery for the United States Navy this stainless iron analysis has been specified. The grade has also been supplied extensively to the chain restaurants and to several hotels.

B. Other Domestic Uses

In the home stainless materials have many uses. They have been applied in many cases to replace either chromium plate or nickel plate. A brief list of the applications for domestic use follows:

- Drawer and door pulls
- Fire screens and andirons
- Mirror and picture frames
- Radio parts
- Electrical fixtures and reflectors
- Book ends
- Curtain rods and fixtures
- Door and window screens
- Door and window trim
- Washing machines
- Refrigerators
- Plumbing and plumbing fixtures
- Kitchen cabinets
- Ice cream freezers
- Fireless and steam pressure cookers
- Table tops
- Oil and electric stoves

Stainless appliances are attractive to the housewife as a damp cloth and a dry cloth are all that she needs to keep them spotlessly clean.

C. Architectural Work

1. Outdoor Trim

The greatest single and most spectacular applications of stainless are for architectural trim on buildings. For this purpose the Krupp 18 and 8 type has been generally used, possessing as it does, the best resistance to the corrosive influences of the weather.

There have been several applications of stainless for this purpose, the outstanding examples in the United States being the Chrysler and Empire State Buildings in New York City.

a. Chrysler Building

The Chrysler Building at 405 Lexington Avenue, New York City, was opened to tenants on April 1, 1930, and was dedicated by its builder, Mr. Walter P. Chrysler, "as a sound contribution to business progress."[(1)]

The Chrysler Building is certainly an excellent example of the progress in the use of stainless materials and its architects pioneered in the use of this material for exterior building trim.

Some 500 tons of stainless material were used in the erection of the Chrysler Building, the chief application

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(1) Dedication of the Chrysler Building, booklet published by Chrysler Building Corporation, p. 32

being for the tower which is 185 feet high. 4,500 sheets of stainless were used in covering the tower. Stainless steel rivets and bolts fasten these sheets to the framework of the building, so that no other metal can spread corrosion to it.

In the Chrysler Building stainless was also used for building trim, for grilles, copings, and for store fronts on the street floor.

The matter of upkeep is an important one on store fronts, and stainless will doubtless come to be very generally used for this purpose in the future.

Practically all of the stainless used in the construction of the Chrysler Building was furnished by the Crucible Steel Company of America in their "Rezistal" grade, manufactured under license issued to them by the Krupp Nirosta Company.

b. The Empire State Building

The Chrysler Building, at the time of its completion in 1930, was the tallest building in the world and represented a stupendous architectural achievement. However, its triumph was short lived, for in the brief space of one year an even more impressive architectural feat was accomplished in the erection of the Empire State Building at 250 Fifth Avenue, New York City.

In the construction of the Empire State Building, which is 1248 feet high, some 300 tons of the Krupp 18 and 8

material were used for window trim, ornamental sunbursts, store fronts, and on the 250 feet high dirigible mooring mast which tops this structure.

The window trim strips extend almost 1248 feet high. The windows are arranged in lines, and the piers are so constructed that a very interesting effect is obtained through refraction of light rays. The arrangement of the metal trim strips on the Empire State Building also allows the elevators to be set in the walls of the building, thus saving considerable floor space.

Half of the stainless used in the Empire State Building was supplied by the Republic Steel Corporation in their "Enduro" grade, and the other half was supplied by the Allegheny Steel Company in their "Allegheny Metal." Both companies manufacture under licenses issued by the Krupp Nirosta Company.

On the tower and mooring mast of the Empire State Building some 150 tons of aluminum and 20 tons of stainless were used. Both of these metals are very much lighter in weight than ordinary carbon steel, which is an important consideration, in view of the importance of the feature of swaying on such tall buildings.

c. Other Buildings Using Stainless

The Chrysler and Empire State Buildings are cited because they represent the most publicized and largest single uses of stainless in this country to date, as well as the

pioneer developments in architectural use.

However, there are several other buildings on which stainless has been used, notably the Savoy Hotel in London, whose facade is trimmed with stainless, the Earl Carroll Theatre in New York City, where a considerable quantity of stainless was used to decorate the lobby, and the Buffalo General Electric Building, Buffalo, New York, where the elevator entrances are built of stainless 18 and 8. Stainless was also used to some extent for trim in Radio City Music Hall, and in the Insurance Company of North America Building, both located in New York City, and more recently on the Richman Bros. Building in Detroit.

d. Requirements of Stainless for Building Trim

When selecting a stainless material for outdoor building trim, it is very essential that the material possess great corrosion resistance to the weather, as well as to moist salt air, and to whatever chemicals may be present in the air in that locality. The Krupp 18 and 8 type was selected as possessing the best corrosion resistant qualities for such applications. This material can also be supplied in a form and temper that lends itself easily to the necessary forming operations.

e. Performance Record of 18 and 8 on Building Trim

Although numerous laboratory tests had been made on the 18 and 8 analysis prior to its selection for outdoor trim on

the Chrysler and Empire State buildings, there was no absolute certainty that the material would prove entirely resistant to actual corrosive conditions of the weather. This is particularly true in a manufacturing locality, such as New York City, where it is impossible to determine in advance just what gases and chemicals will be released into the air from manufacturing plants. Consequently, even the best planned laboratory tests fail to approximate the actual service conditions. Therefore, an examination of the metal on the Chrysler and Empire State buildings was awaited with interest.

Such an examination was made in the spring of 1933. The material on the Chrysler Building showed that the finish had dulled a little, and there were some noticeable streaks due to rain and dust, but the original luster of the steel remained.

The Empire State showed some discoloration by dust and rain, but this wiped off easily with a pocket handkerchief, and the steel seemed to retain its original luster.

Examination of both buildings seemed to indicate that better results were being obtained on the Empire State Building than on the Chrysler, although both applications were considered satisfactory. The difference in results is probably traceable to the increased knowledge in the metallurgy of the material, gained in the year that intervened between the erection of the two buildings.

One interesting feature on the Empire State Building developed shortly after its erection when large spots of rust were discernible on some of the metal panels. This occasioned some distress on the part of the steel manufacturers, but examination showed that such rust was due to corrosive elements washed out of the concrete by rain, and deposited on the stainless panels. These panels were washed a couple of times, and the corroding ceased.(1)

2. Flood Lights

Because of its very high reflecting properties stainless, particularly the Krupp 18 and 8 type, has been used for reflectors for flood lights, and for outdoor advertising which is illuminated at night.

Some examples of its use in this manner were evident at the Century of Progress Exhibition in Chicago last summer, but it was not employed to any extent there due to the high cost of such lighting facilities, and the temporary nature of the buildings.

3. Preservation of Old Buildings

Monypenny mentions one rather interesting use of stainless abroad in the preservation of St. Paul's Cathedral in London. The dome of the cathedral was reinforced by stainless chains, and the piers supporting the dome were also reinforced by inserting tie bars of stainless steel.(2)

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(1) Grossman, Marcus A., Performance of Stainless Steels, Iron Age, July 20, 1933. p. 19 ff.
(2) Monypenny, J. H. G., Stainless Iron and Steel, p. 522

No such applications have yet been made in the United States, but because of the enormous tensile strength of the stainless material, and its light weight, there is every reason to believe that it will prove very useful for the restoration and preservation of old buildings.

4. The Future of Stainless in Architecture

The future trend of stainless in architecture is somewhat doubtful. Now that stainless is no longer a novelty, it seems that there will hardly be another building that will use such large quantities of the material in the manner in which it was used on the Chrysler Building and the Empire State Building. There is, of course, no guarantee that this will be the case, but we Americans are known to be extremely progressive, and it is not unlikely that the architects of the next skyscraper of any size like the Chrysler or Empire State will have something entirely new in outdoor architectural design to offer to the public. That, however, is a point that the future will decide.

There seems to be little doubt that, in view of its excellent adaptation for store fronts, and the small amount of labor required for upkeep, stainless will be employed quite largely for use in this manner, as well as for doors, elevator casings, and interior decorative work, where the tonnage involved would be considerably less than that required for extensive outdoor architectural trim.

Just what the actual outcome will be is, at the present time, "anybody's guess."

D. Automotive Industry

At the present time the major portion of the stainless metals manufactured in the United States is being used by the automotive industry. Although building operations have provided the most spectacular use of stainless, the automotive industry has provided the most consistent consumers.

1. Stainless for Automobile Fittings and Trim

Several of the lower priced automobiles, particularly Ford and Chevrolet, have adopted stainless extensively on their new models in place of the chromium plated or nickel plated metals used in the past. Some of the applications have been for radiator caps, hub caps, windshield channels, headlights, and cowl bands. Stainless has also been used for many of the interior fittings of automobiles. The advantages of its use are apparent, as contrasted with the easily tarnishable chromium plated or nickel plated metals.

Stainless iron with a chromium content of 16.0 to 18.0 per cent has proved entirely satisfactory for this purpose. It is sufficiently corrosion resistant, is much cheaper than the Krupp austenitic type, and also lends itself better to the deep stamping and drawing operations required in forming automobile parts.

Packard, however, have used the Krupp austenitic type for wheel spokes, as this grade is particularly resistant to the corrosive action of water, snow, and salt.

No statistics as to the amount of stainless used in the automotive industry are available, due to the fact that the material is supplied by some independent producers, as well as by the licensees of the American Stainless Steel Company, and the Krupp Nirosta Company, also due to the fact that the automotive companies themselves are not desirous of releasing information regarding their fabricating and manufacturing processes.

2. Stainless for Valves and Other Engine Parts

Alloy steels not strictly of the stainless family, but allied to it, are chiefly used in the United States for the manufacture of automobile valves and other engine parts. No one in the United States today expects a car to last as long as the 1920 Dodges and Fords. Consequently, the use of the real stainless steels for engine parts has not been as broad as it might be.

Steel analyzing 12.0 to 14.0 per cent chromium has proved entirely satisfactory for pump shafts, and some carburetor by-pass valves are made from very high chromium alloys. However, for engine valves no material yet developed in this country has proved more satisfactory than the high chromium silicon alloy,[1] although it seems likely

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(1) Mitchell, Walter M. Uses and Applications of Stainless Steels, Iron Age, May 11, 1933, p. 12

that the development of the "anti-knock" gasolines may necessitate the development of a suitable stainless alloy to resist their corrosive properties.

E. Aircraft Applications

Because of its high tensile strength, and lightness in weight, stainless has proved of benefit in the construction of many airplane parts, particularly for bolts, gauges, antennae, transformers, radio parts, and hardware.

It is also used very extensively in landing fields for reflector lights, and searchlights.

As in the case of automobiles some use has been developed for stainless valves, particularly in England during the War, but in many tests that were conducted recently, it was found that other alloy steels, of somewhat related grades, have proved quite as satisfactory as stainless in actual operation.

F. Steam and Hydraulic Plants

While other types of alloy steels are just as satisfactory for use in automobiles and airplanes, stainless valves have been successfully adopted in connection with steam and hydraulic pressure.

For this purpose a steel containing 12.0 to 14.0 per cent chromium has proved very suitable as it can be hardened to give a Brinell reading of 370 to 400.(1) The use of this material, however, necessitates a valve of special design.(2)

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(1) Testing on the Brinell machine is the customary test for determining the hardness of any steel

(2) Monypenny, J. H. G., Stainless Iron & Steel, p. 527

If there is any possibility of an electrochemical attack, some other type of steel is used in the valves, preferably the Krupp 18 and 8 type, which offers greater resistance to this particular type of corrosion.

For rams and spindles in hydraulic plants, stainless steel has largely replaced bronze. Stainless is more resistant to corrosion than bronze, and also can be heat treated to a much greater degree of hardness.

Monypenny cites the following cases to illustrate the resistance offered by stainless rams in hydraulic plants:

> "The rams were 1-1/2 inches in diameter. After one month's service, one of them, made of bronze, had been reduced .014 inches by wear. The other ram, of stainless steel, wore only .005 inches in nine months. The pressure in each case was two tons per square inch." (1)

G. Turbine Blades

Of all the engineering applications of stainless metals, that for turbine blades is probably the most important. This is because the modern tendency to use very high temperatures and pressures in steam plant equipment has put a very severe tax on the materials used in the construction of turbines.

The type of stainless used depends upon the construction of the turbine, and the conditions of operation, but in general stainless iron of the 12.0 to 14.0 per cent

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 531

chromium range has proved suitable.

The selection of the proper grade of stainless for this application is a highly technical problem, but for purposes of this thesis it is sufficient to say that no steel yet developed can meet the requirements of turbine blades as satisfactorily as stainless iron.(1)

H. <u>Chemical Industry Applications</u>

The uses of the stainless metals in the chemical industry could be selected as a suitable topic for development in a technical thesis, so varied and complex are the applications of stainless in this industry.

In some cases stainless has entirely revolutionized the chemical processes. This is particularly true in the manufacture of synthetic ammonia, and in the nitric acid industry. One metallurgist has gone so far as to remark that "stainless steel might have been discovered several years previously if nitric acid, rather than sulphuric acid, had been used in making the corrosion tests."(2) Today the total investment in acid plants in the United States would run well into millions of dollars.(3)

The chemical industry's chief problem has been corrosion. This has been very costly, due not only to the delays in production necessitated by stoppage for repairs, and the expense of replacements, but also to the possibility

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(1) Monypenny, J. H. G., Stainless Iron and Steel, p. 533 ff.
(2) Speaker at Convention of American Society for Steel Treating, Boston, 1925. Name unknown.
(3) Mitchell, Walter M., Uses and Applications of Stainless Steels, Iron Age, May 11, 1933, p.743

of contamination caused either by catalytic action, or the direct absorption of corroded materials.

No type of stainless yet developed has proved a panacea for all the troubles of the chemical industry. The type to be adopted depends both upon the chemical attack encountered, and the construction of the part. In many cases the lower priced stainless irons have been found to offer quite as satisfactory resistance as the more expensive austenitic types. For some of the more severely corrosive attacks "special purpose" alloys have been developed, and there is scarcely any application in the chemical industry where some form of stainless cannot be made to offer infinitely better corrosion resistance than is possible with the use of carbon steels.

The textile industry, particularly that branch concerned with the dyeing of materials, has benefited enormously from the use of the stainless alloys in the construction of dyeing machinery.

I. Oil Industry Applications

Next to the automotive industry the largest consumers of stainless materials are the oil and food industries, who use about equal amounts annually.

1. Oil Pumps

In the oil industry one of the most serious problems is corrosion, due to the amount of sulphur compounds present

in crude oil. "It is estimated that the cost of rust and corrosion in this industry runs well over one hundred million dollars a year, and it is a direct tax on every user of oils and gasoline."(1) Thus the advantages accruing from the use of stainless are readily apparent.

On oil pumps the demand is not only for a material which will resist the attack of sulphur, but for a material which will retain considerable strength at high temperatures. Several steels have been developed, which satisfactorily resist the attack of sulphur, but only the stainless chromium-bearing steels offer the desired combination of qualities for successful operation in oil pumps.

2. Oil Burners for Domestic Use

In the construction of oil burners for domestic use the stainless irons have been widely adopted, particularly those within the 16.0 to 18.0 per cent chromium range. These materials offer resistance to corrosive attack from the oil, and also are capable of being operated at high temperatures without warping or cracking.

This is a particularly important application for New Englanders, due to the growing use of oil for heating and cooking purposes in homes. Several factors have contributed to the widespread adoption of oil for domestic use in New England, chief of which are the absence of any

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(1) Mitchell, Walter M., Uses and Applications of Stainless Steels, Iron Age, May 11, 1933. p. 743

large forest areas, the high price of coal, and the lack of natural gas. Under these conditions, oil proves to be the cheapest, and in many respects the most satisfactory, agent for domestic use.

A new industry has developed in New England because of this fact, that of building and marketing oil burners for domestic use. One of the best known companies adopting stainless for this purpose is the Florence Stove Company at Gardner, Massachusetts, but there are several smaller manufacturers throughout New England who are using very sizable quantities of stainless material for oil burner equipment.

J. Food and Packing Industries

Probably no other industry is more concerned with the problem of corrosion resistance than the food industry. Here stainless materials offer absolute freedom from contamination, as well as an attractive appearance.

For canning and preserving machinery, for all sorts of food packing, for restaurants, hotels, and soda fountains, stainless equipment is very desirable. Stainless has been widely adopted for bread making machinery, and for machines for making ice cream.

In the dairy industry stainless is being used extensively, and here it offers a decided advantage in that the milk can be pasteurized in the stainless cans.

In the meat packing industry the applications of stainless are endless. The U. S. Department of Agriculture recommends the adoption of the Krupp 18 and 8 type for meat packing equipment. The advantages due to the prevention of losses by reason of contamination, shutdown caused by government inspection, etc., can be readily realized, and such occurrences can be entirely prevented by the adoption of stainless steel equipment.

In retail meat shops the advantages of clean table tops and spotless stainless counters cannot be overlooked.

In no other way do we come in direct contact with the advantages to be gained from the use of stainless equipment as we do in the food and meat packing industries. Public opinion has a very close and direct effect upon these industries, which probably accounts for the fact that, next to the automotive industry, food offers the widest market for industrial applications of stainless alloys.

K. Golf Club Heads

The use of stainless steel for golf club heads has been growing constantly. One of the largest manufacturers of sporting equipment has begun to supply stainless heads on all of the better grade golf clubs.

The advantage of the use of stainless is that the club will retain a permanent polish, and will not be worn

away by the necessity of renewing the surface, as is required in the case of carbon steel club heads.

A special type of stainless has been developed for this purpose, as the application necessitates a particular type of construction, and a material that will be sufficiently hard, yet will deflect somewhat--rather than snap off--when it comes in contact with the golf ball. The desired effect here is accomplished by a very carefully worked out method of heat treatment of the stainless club head.

L. Gun Parts

The advantages of the use of stainless steel for gun parts need little amplification. It is particularly interesting to note, in this connection, that Mr. Harry Brearley was experimenting on a suitable steel for gun parts when he discovered stainless steel.

The reader can easily understand the benefits to be obtained from gun parts that will neither erode nor corrode.

M. Paper and Pulp Machinery

One of the applications most interesting to New Englanders is that of the use of stainless for paper mill machinery, to replace bronze.

Stainless has several advantages, as compared with bronze, the first of which is that the stainless material

can be rolled to any shape desired, while bronze must be milled to shape from flat rectangular bars. Stainless can be heat treated to give any hardness and physical properties desired, while bronze can be rolled to only very limited hardnesses, and the hardness of bronze in all cases depends upon the rolling operations, while stainless obtains its hardness from a variety of heat treating operations to which it may be subjected.

Stainless iron of the 14.0 to 16.0 per cent chromium variety has been very widely adopted throughout New England for use in Jordan Engines and Beating Machines. It has proved to be very successful on such applications, particularly in resisting the corrosive action of the acids and chemicals commonly used in the manufacture of paper.

No one type of stainless alloy can be recommended for use in all cases. It is the custom of the steel companies to obtain samples of the bleaching liquors used in making the paper, and then to run mill laboratory tests to determine the type of stainless material, and the heat treatment necessary, to render the most satisfactory corrosion resistant qualities for that particular paper mill.

Superintendents of paper mills are, on the whole, most enthusiastic about the use of stainless for making paper. Some of them have hailed its use as the greatest

advancement in the manufacturing of paper within the past twenty years, and one of the largest mills in the United States, engaged in the manufacture of fine writing papers, has begun to adopt the stainless material for use throughout all its plants. As replacements of machinery are necessary, bronze and ordinary carbon steel equipment is discarded, and stainless is purchased in their stead.(1)

N. Soap Manufacturing Machinery

The use of the stainless materials in the soap manufacturing industry might properly be considered under the applications to the chemical industry. Stainless of the Krupp 18 and 8 type has proved very satisfactory in the manufacture of soap, chiefly because of its resistance to the corrosive action of many of the chemicals used.

Stainless has also been adopted for the storage of glycerine, which is needed in its purest form for the manufacture of many types of soaps.

O. Railroad Equipment

It is only very recently that stainless material has been used in the manufacture of railway coaches. In this particular application, a saving of some 75 per cent in the weight of coaches can be effected by the use of stainless. The economy of operation in this case is quite apparent.

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(1) Name of company purposely withheld, by request.

Quite recently a two car train was delivered to the Texas & Pacific Railroad. This train is constructed entirely of stainless, except the floors of the baggage and mail compartments, and some interior trim of the coach. This train is to be run from Fort Worth to Texarkana.(1)

Stainless alloys have also been employed to some extent for valves on locomotives.

However, the present financial condition of the railroads has probably prevented the wide adoption of stainless materials for any purposes, as all purchases of railroad equipment have been kept at an absolute minimum. For this reason it is most unlikely that stainless will be used to any appreciable extent for railroad equipment until there is a considerable improvement in railroad business.

P. Stainless Steel Tubes

The stainless metals have been widely used in the manufacture of all sizes of tubes. It is impossible to estimate with any degree of accuracy the number of uses for tubing in the various manufacturing plants throughout this country, as well as in the oil wells, distilleries, etc. To all of the corrosive elements present in such applications stainless is, or can be made, resistant, and for such uses it has been very widely adopted.

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(1) Railway Age, November 11, 1933 p. 692

Q. Stainless for Hospital Equipment

In no other place are the freedom from all corrosive influences and the need for spotless cleanliness of greater importance than in a hospital. The uses of stainless here are greatly diversified.

Stainless can be used to advantage in hypodermic needles, in surgical instruments, where constant sterilization wears away the superficial coating that is given to ordinary carbon steels. The operating equipment and all of the operating room fixtures offer a splendid opportunity for the use of a thoroughly sanitary metal which strong chemicals and acids cannot deface nor destroy.

1. The Springfield Hospital

The new Springfield Hospital at Springfield, Massachusetts, has a splendid installation of stainless in its diet kitchen where the sinks, cabinets, trays, and food carriers are entirely stainless throughout their construction. The steaming table is also made entirely of stainless metal.

This was the first hospital in New England to have such an installation. The material used in this case was chiefly of the Krupp 18 and 8 type, furnished by the Crucible Steel Company of America.

IX. RESUME OF THE ADVANCEMENT MADE IN THE USE OF THE STAINLESS ALLOYS

In summary, the stainless alloys may be said to meet two groups of requirements, not necessarily independent, as follows:

> "(1) Requirements for corrosion resistance. This includes resistance to high temperatures, oxidation, for this is merely a form of corrosion. Under this should also be included requirements for decorative materials, since the ability to maintain an untarnished surface is merely the evidence of unusually complete resistance to corrosive attack.
>
> "(2) Requirements for unusual mechanical properties of hardness, strength, toughness, or ductility. With this should be included requirements for resistance to wear and abrasion." (1)

I have attempted to show in the preceding pages the manner in which the stainless alloys have been adapted to meet these requirements, and the success that has been attained.

In any consideration of the development of stainless alloys it is extremely important to bear in mind the fact that only twenty years have elapsed since Brearley made his first discoveries, which were followed shortly thereafter by the Haynes and Krupp developments. All of these developments were delayed approximately five years by the World War. In fact, it was considerably later than

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(1) Mitchell, Walter M. Uses and Applications of Stainless Steels, Iron Age, May 11, 1933. p. 743

this that the Krupp steels were introduced into the United States.

Some understanding of the importance and the influence of the stainless steels may be gained from their wide and diversified applications. "Their uses vary from hypodermic needles to the machinery needed in oil refineries, from the very mild corrosive action of milk to the strong corrosive action of various acids used in the chemical industry, from household novelties to decorations for the tallest buildings in the world."(1)

To what extent the use of stainless metals has cut down the estimated annual loss by corrosion which Hadfield fixes at $3,500,000,000 is a matter of conjecture, on which only the most foolhardy would venture an opinion. However, there is no questioning the fact that the introduction of the stainless alloys has opened up many new markets and aided in placing the steel industry where it should be, "holding the undisputed leadership it deserves as producer of the world's most beneficent material."(2)

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(1) Mitchell, Walter M., Uses and Applications of Stainless Steels, Iron Age, May 11, 1933 p.743
(2) Editorial, Steel Has Another Job, Iron Trade Review, January 6, 1927

X. FUTURE POSSIBILITIES OF THE STAINLESS ALLOYS

What the future trend of the stainless alloys will be, what industrial needs they will fill, where they will find their markets, are all questions that only time will answer. In our rapidly changing economic structure today's luxury becomes tomorrow's necessity.

Our grandfathers saw the development of the transcontinental railroads. We of the present generation have witnessed the rapid development of the automobile as a means of transportation, and in more recent years, the development of the airplane. What to our forefathers was a journey of days, is to us a journey of hours, or minutes.

In 1912, the Woolworth Building represented the pinnacle of structural achievement. In 1934, it is "one of the buildings on Broadway." In 1930, the Chrysler was the most up-to-the-minute office building in New York City. Its construction had scarcely ceased when it was completely outclassed by the Empire State Building.

What will happen next in any field of industrial enterprise is your guess--or mine.

There is no doubt that a generous Patent Office in Washington has granted an imposing array of patents on analyses of stainless alloys, and on processes of manufacture, in which there was bound to be some overlapping.

In this connection, Judge Coleman's decision in the suit brought by the American Stainless Steel Company against the Rustless Iron Corporation is particularly interesting. He ruled that the Clement product patent, on which the suit was based, was invalid because of the prior inclusion of the Clement analysis under the specifications of the Haynes patent. His remarks, as quoted below, are quite pertinent:

> "Thousands of tests and experiments have already made the metallurgy of iron and steel a broad and highly developed field. A claim to monopoly of any part of that field by any one entering it at this late day can be sustained only by clear proof of discovery of something there not before found, or an invention of something not before there." (1)

The case has not been appealed to the higher court, and the decision in this matter will no doubt have an important bearing on the future of the stainless alloys in this country.

However, from a study of the various patents, it is very evident that many of them could not be successfully defended in court. Moreover, litigation over patent rights and infringements is always very costly, due to the expert testimony necessary; such cases are usually prolonged for several years, at the end of which all the victorious party gains is a legal decision ordering the infringing party to "cease and desist."

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(1) Federal Supplement Vol. 2, 1933. p.756

It would seem, therefore, in view of the conflicting patents, that the logical move would be for the major steel manufacturers to merge, not only their patents, but their experience in development and production of the stainless alloys. This would doubtless result in considerable benefit to all concerned.

It is probable that some standards, such as those adopted by the American Society for Testing Materials, could be decided upon, that the variety of the stainless alloys could be standardized somewhat, and a lesser number of grades manufactured, with resultant economy of operations accompanied by price reductions.

In the absence of any move in this direction the reader must bear in mind the fact that the majority of the stainless patents obtained in the United States have several more years to run, in which event the price feature will continue to be controlled by the various companies holding the major patent rights on these materials.

The relatively high prices of the stainless alloys have been an important factor in their industrial applications. Many features have contributed to make their manufacture expensive. The educational and development work to date has been costly, and, in addition, the inherent physical properties of these stainless alloys will

always make their production and processing costs greater than the costs on corresponding products in ordinary qualities of steel.

To these factors must be added the extra expense which lack of suitable equipment and of satisfactory production volume on the stainless grades has entailed.

It is not possible to forecast with any degree of accuracy the effect of price reductions on the volume of stainless tonnage sold, as the exact extent to which the price factor has influenced, or will influence, industrial applications of stainless alloys is a moot question.

There has been one rather interesting development apparent in this connection. In certain applications where stainless was sold in direct competition with bronze, it developed that until 1931 the unit cost was only slightly more on stainless than on bronze, and a very favorable portion of the tonnage placed was for stainless materials. However, since the very marked decline in the price of copper, there seems to be a tendency to place relatively more tonnage in bronze, although on these particular installations stainless has proved to give satisfactory service.

This is cited simply as an interesting case. It is not beyond the realm of probability that other factors--

influence by the holders of stocks in the copper companies, or mills engaged in the production of bronze-- , have to some extent controlled these applications.

In the final analysis it is public demand which determines the product that will be sold. Therefore, on consumer goods, the extent to which the consuming public can be educated in the use of the stainless alloys, and the development of a desire and willingness to pay twice as much for something that will last three times as long, will determine the future demand for these materials.

On industrial applications it will be necessary to educate the users to figure not the initial cost of a stainless installation, but the cost in terms of service. It is scarcely probable that the cost of the stainless alloys, even the cheapest grades, will ever be as low as the cost of ordinary carbon steels. However, in cases where carbon steel has proved to be unsatisfactory in service, where the conditions can be met by the stainless alloys, and where the advantages gained will justify their somewhat greater cost, their commercial utility will be realized.[1]

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(1) Mitchell, Walter M., Uses and Applications of Stainless Steel, Iron Age, May 11, 1933 p. 14

A list of the possible applications of stainless alloys would be a roll call of almost every manufacturing process in the United States, but wherever there is a metal problem involving

great strength
resistance to rust
resistance to stain
resistance to tarnish
resistance to corrosion
resistance to high temperatures
resistance to erosion
resistance to abrasion
plating, polishing, painting or enameling (1)

"STAINLESS--THE METAL OF ENDLESS POSSIBILITIES" can be made to solve it.

F I N I S

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(1) American Stainless Steel Company booklet, Stainless in Industry, p. 20

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